REMOVAL OF BACTERIA BY ZEOLITIC WATER SOFTENERS[1,2]

By Gerald C. Baker[3]

I. INTRODUCTION

There is a growing demand for soft waters for both domestic and industrial uses. The chief industrial uses are for laundries, boiler houses, dying plants, hair dressing establishments, etc. Since zeolitic softeners produce a water of zero hardness and are more economical and simple to operate than plants employing chemical and other precipitation methods they are rapidly gaining public favor.

The questions are often asked whether zeolitic softened water is more beneficial for drinking purposes than untreated water and whether such softened water is suitable for bottled drinks. Without entering into the question of the therapeutic values of different drinking waters, it suffices to say that all authorities agree that a good drinking water must be one which is safe bacteriologically. The question naturally arises then as to what, if any, sterilizing action these zeolitic filters have. Duggan (1) and Bencke (2) refer to a certain type of permutit as having a sterilizing action, while an anonymous article (3) claims that microbes are wholly removed when water is passed through it. With the exception of these references no additional information could be found on the subject. It was with the view of definitely establishing what sterilizing action common zeolitic water softeners possess, that this work was undertaken. No references at all were found concerning the use of zeolitic softened waters for bottled drinks.

[1] Read by abstract at the meeting of the Iowa Section, at Omaha, Nebraska, November 1, 1921.

[2] This work was carried out under the direction of the Department of Pathology and Bacteriology of the State University of Iowa.

[3] State University of Iowa, Iowa City, Iowa.

II. EXPERIMENTAL

(*A*) *Apparatus and materials*

In attacking the problem of the quality of zeolitic softened water for drinking purposes it was thought best to carry out not only laboratory experiments, but also to conduct tests upon domestic and industrial installations of the common water softening minerals on the market.

The laboratory experiments were carried out in specially prepared apparatus shown in the accompanying photograph.

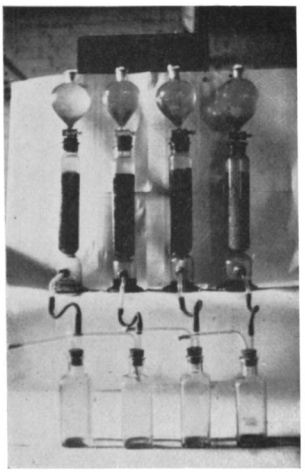

FIG. 1

Equal volumes (250 cc.) of previously used permutit, refinite, borromite, and sand were placed in 12-inch calcium chloride towers which were fitted with 250-cc. separatory funnels, which served as feed reservoirs for the water which was being filtered. The minerals in all cases were supported by a layer of glass wool. Siphon tubes led from the reservoirs of the calcium chloride towers to 250 cc. bottles. These bottles were supplied with glass outlet tubes, and served as receivers for the filtered water. After opening the stopcocks of the separatory funnels and plugging all openings with cotton, the apparatus was sterilized in an autoclave at 15 pounds pressure for thirty minutes. When thoroughly cooled the testing solutions were slowly passed through the minerals and samples collected aseptically for analysis.

Three domestic units and one commercial zeolite water softening installation were tested at irregular intervals. The domestic units comprised permutit, refinite and borromite installations situated in the basement of Close Hall of the University of Iowa and are intermittently operated. The commercial unit examined was a permutit filter in daily use by the New Process Laundry of Iowa City, Iowa. The domestic units in Close Hall are supplied by the University of Iowa water supply which is derived chiefly from deep wells, but which is supplemented at all times by a variable quantity of the Iowa City city supply. The New Process filter is fed by the Iowa City city supply which is derived from infiltration galleries beneath the Iowa River. The water is coagulated with alum and lime and is filtered through rapid sand filters followed by sterilization with liquid chlorine.

In order to test further the quality of zeolitic softened water for drinking purposes and its adaptability for use in bottled drinks an attempt was made to sterilize the filter bed of a domestic zeolitic softener with varying amounts of sodium hypochlorite, and tests were made on the filtered water to determine the quality of the water delivered. The most suitable type of softener for these tests seemed to be a domestic borromite installation, due to its simplicity of operation and the convenience of applying the sodium hypochlorite. The sodium hypochlorite could be added directly to the softener through the top opening at the same time as the salt used for the regeneration of the system. With the other types of zeolitic installations, which are reconditioned with a brine solution prepared outside the softener, it would be more difficult to control the amount of liberated chlorine supplied to the softener. The borromite system could be reconditioned in ten to fifteen minutes, whereas refinite and permutit softeners require six to nine hours for reconditioning. Sodium hypochlorite was used instead of bleaching powder for sterilizing the filter bed, since it would not add hardness to the filter. It was not thought advisable to use liquid chlorine.

Through the courtesy of the Borromite Company of Chicago, these tests were carried out in their laboratories using two D-9 type softeners and water from the Chicago city supply.

(*B*) *Methods of analysis*

The methods of analysis employed were those of the American Public Health Association, as outlined in "Standard Methods of

Water Analysis," 1920 edition. Counts were made at the end of forty-eight hours on plain agar and at the end of twenty-four hours on litmus lactose agar. The number of acid colonies on the litmus lactose plates was also recorded. Fermentation observations were made on 10-cc. and 1-cc. samples of water in lactose broth, at the end of twenty-four and forty-eight hours. All gas formation was confirmed on eosin-methylene-blue agar plates, incubated at 37°C. for twenty-four hours. The quality of the filtered water was judged according to the number of colonies produced on the agar plates and by the presence or absence of gas in lactose broth.

In the sterilization experiments bacterial counts were made as a check to determine the effectiveness of the hypochlorite treatment. These counts were made at room temperature (26°C) at the end of twenty-four and forty-eight hours on plain agar. The agar was supplied by the Chicago Health Department. Since the Chicago supply seldom contains gas formers, fermentation tests were not made as previous work had shown the entire absence of B. coli in zeolitic softened water, when the raw water was free from sugar-splitting organisms. The starch iodide test was made on the water used for reconditioning to ascertain at what point all of the excess chlorine had been washed out of the mineral.

(C) *Results*

1. Laboratory tests. Since the quality of drinking water is largely judged on the basis of the presence or absence of Bacterium coli, it was thought best to employ for the laboratory experiments a water which was known to contain this organism. Raw infiltration gallery water from the Iowa City water plant, therefore, was used. This water was passed through the laboratory filters, the experiments on sand serving as a check upon the zeolitic filters.

The water was passed through the filters at a rate of 250 cc. in fifteen minutes, a rate comparable to the ordinary softening rate for these materials. Samples were taken for analysis from each 250 cc. passed. The results are given in tables 1 and 2.

At the time that the bacteriological tests were being run, determinations were made on the removal of turbid matter from the raw water being passed through the filters. The turbidities remaining are recorded in table 3.

A physical analysis of the minerals used was made. The uniformity coefficient and the effective size was determined according

TABLE 1

Removal of bacteria by zeolitic water softeners—Test 1. Laboratory filters

SAMPLES	COLONIES PER CUBIC CENTIMETER			FERMENTATION TESTS			
				Lactose broth—37°C			
	Plain agar 20°C.—48 hours	Litmus lactose agar 37°C.—24 hours.	Acid colonies.	24 hours		48 hours	
				10 cc.	1 cc.	10 cc.	1 cc.
Raw river	5000–6000	6000–10000	0–0	1/1	2/2	1/1	2/2
Refinite, 1st 250 cc	5000–6000	3000– 2500	0–0	1/1	1/2	1/1	2/2
Refinite, 2nd 250 cc	2000–1500	3000– 2500	0–0	1/1	2/2	1/1	2/2
Refinite, 3rd 250 cc	2800–3000	3200– 3000	0–0	1/1	2/2	1/1	2/2
Permutit, 1st 250 cc	3000–3000	2100– 2200	0–0	1/1	1/2	1/1	2/2
Permutit, 2nd 250 cc	4000–3500	3000– 2950	0–0	1/1	2/2	1/1	2/2
Permutit, 3rd 250 cc	2300–2800	3200– 3000	0–0	1/1	2/2	1/1	2/2
Borromite 1st 250 cc	2000–2500	2400– 2000	0–0	1/1	2/2	1/1	2/2
Borromite, 2nd 250 cc	3000–2000	3500– 3100	0–0	1/1	2/2	1/1	2/2
Borromite, 3rd 250 cc	2100–3000	3200– 3000	0–0	1/1	2/2	1/1	2/2
Sand, 1st 250 cc	4100–6000	5000– 8000	0–0	1/1	2/2	1/1	2/2
Sand, 2nd 250 cc	4000–5000	750– 900	0–0	1/1	2/2	1/1	2/2
Sand, 3rd 250 cc	4000–2000	2200– 2000	0–0	1/1	2/2	1/1	2/2

Note: All gas formation was confirmed on eosin methylene blue plates and in every case gave positive tests for B. coli.

TABLE 2

Removal of bacteria by zeolitic water softeners—Test 2. Laboratory filters

SAMPLES	COLONIES PER CUBIC CENTIMETER			FERMENTATION TESTS			
				Lactose broth—37°C.			
	Plain agar 20°C.—48 hours.	Litmus lactose agar 37°C.—24 hours	Acid colonies	24 hours		48 hours	
				10 cc.	1 cc.	10 cc.	1 cc.
Raw river	7500–8000	2000–2500	0–0	1/1	2/2	1/1	2/2
Refinite, 1st 250 cc	5000–7000	500– 450	0–0	1/1	2/2	1/1	2/2
Refinite, 2nd 250 cc	4500–4500	750– 800	0–0	1/1	2/2	1/1	2/2
Refinite, 3rd 250 cc	5000–4500	500– 500	0–0	1/1	2/2	1/1	2/2
Permutit, 1st 250 cc	2500–3500	500– 600	0–0	1/1	2/2	1/1	2/2
Permutit, 2nd 250 cc	1900–1800	600– 600	0–0	1/1	2/2	1/1	2/2
Permutit, 3rd 250 cc	2750–2600	850– 700	0–0	1/1	2/2	1/1	2/2
Borromite, 1st 250 cc	3000–2750	400– 400	0–0	1/1	2/2	1/1	2/2
Borromite, 2nd 250 cc	3000–1200	250– 400	0–0	1/1	2/2	1/1	2/2
Borromite, 3rd 250 cc	2000–2000	350– 400	0–0	1/1	2/2	1/1	2/2
Sand, 1st 250 cc	3500–2500	400– 400	0–0	1/1	2/2	1/1	2/2
Sand, 2nd 250 cc	2500–2000	350– 230	0–0	1/1	2/2	1/1	2/2
Sand, 3rd 250 cc	1800–2900	400– 250	0–0	1/1	1/2	1/1	2/2

Note: All gas formation was confirmed on eosin methylene blue plates, and in every case gave positive tests for B. coli.

to the method given by Flinn, Weston and Bogert (4). The results of the tests are given in table 4.

2. Tests upon domestic and industrial installations. Samples were collected periodically for analysis from the units already described. The results are recorded in tables 5, 6, 7, 8, 9 and 10, and represent the conditions of normal operation of the domestic softeners and the commercial permutit installation.

TABLE 3

Reduction of turbidity on filtration of water through zeolites

	TURBIDITIES IN PARTS PER MILLION					
	250 cc. water passed, Test 1			250 cc. water passed, Test 2		
	First	Second	Third	First	Second	Third
Raw water	400			290		
Refinite	420	170	160	180	120	130
Permutit	190	125	110	100	100	100
Borromite	110	80	40	110	50	40
Sand	60	50	30	20	15	10

TABLE 4

Physical analysis of zeolite samples

	UNIFORMITY COEFFICIENT	EFFECTIVE SIZE
		mm.
Refinite	1.55	0.524
Permutit	1.89	0.380
Borromite	1.54	0.221
Sand	1.76	0.261

Since the domestic units were operated only intermittently, they represent a condition similar to that of any household softener. Before samples were collected for analysis the water was allowed to flow through the filters for five minutes. The samples on April 27, 1921, were collected after the softeners had stood idle for some time. They were then reconditioned and the samples on April 29 were collected immediately after zero hardness water was obtained from each softener. Additional samples were taken for analysis on May 2. The tests on June 2 were made immediately after reconditioning. Additional tests were made on June 6 and 7, before the capacities of the softeners had been exhausted.

TABLE 5

Analysis of samples collected April 27, 1921

SAMPLES	COLONIES PER CUBIC CENTIMETER			FERMENTATION TESTS	
	Plain agar 20°C.—48 hours	Litmus lactose agar 37°C.—24 hours	Acid colonies	Lactose broth 37°C.	
				24 hours 10 cc.	48 hours 10 cc.
Raw water, N. P. Laundry.....	9–7	6–8	0–0	0/5	3/5
Filtered water, N. P. Laundry ..	980–850	152–144	0–0	0/5	1/5
Raw water, Close Hall.....	1–7	4000–5000	0–0	0/5	4/5
Refinite filtered water, Close Hall.....	500–800	5000–6500	0–0	0/5	4/5
Permutit filtered water, Close Hall.....	200–230	1270–1210	0–1	0/5	5/5
Borromite filtered water, Close Hall.....	800–600	6000–5400	0–0	0/5	5/5

Note: None of the gas formers confirmed for B. coli when transferred to eosin methylene blue plates.

All the samples from the New Process Laundry were collected in the afternoons, after reconditioning of the system in the morning of the days on which the samples were collected.

TABLE 6

Analysis of samples collected April 29, 1921

SAMPLES	COLONIES PER CUBIC CENTIMETER			FERMENTATION TESTS	
	Plain agar 20°C.—48 hours	Litmus lactose agar 37°C.—24 hours	Acid colonies	Lactose broth 37°C.	
				24 hours 10 cc.	48 hours 10 cc.
Raw water, N. P. Laundry.....	6–5	5–3	0–0	0/5	0/5
Filtered water, N. P. Laundry..	600–500	200–220	0–1	0/5	0/5
Raw water, Close Hall.....	3–2	5000–4000	0–0	0/5	0/5
Refinite filtered water, Close Hall.....	350–240	1200–800	0–4	0/5	0/5
Permutit filtered water, Close Hall.....	220–260	100–270	0–0	0/5	0/5
Borromite filtered water, Close Hall.....	6–1	500–680	0–0	0/5	0/5

TABLE 7

Analysis of samples collected May 2, 1921

SAMPLES	COLONIES PER CUBIC CENTIMETER			FERMENTATION TESTS	
				Lactose broth 37°C.	
	Plain agar 20°C.—48 hours	Litmus lactose agar 37°C.—24 hours	Acid colonies	24 hours 10 cc.	48 hours 10 cc.
Raw water, N. P. Laundry.....	7–10	8–21	0–0	0/5	0/5
Filtered water, N. P. Laundry..	200–250	120–140	0–0	0/5	0/5
Raw water, Close Hall.....	3–5	4000–5000	0–0	0/5	0/5
Refinite filtered water, Close Hall.....	300–200	500–600	0–2	1/5	1/5
Permutit filtered water, Close Hall.....	120–130	90–110	0–0	0/5	0/5
Borromite filtered water, Close Hall.....	2–3	200–300	0–0	0/5	0/5

Note: The gas produced in the Refinite filtered water did not confirm for B. coli.

3. Sterilization experiments. Varying amounts of sodium hypochlorite were placed in the borromite softeners at the same time the salt was introduced for reconditioning the units. The sodium

TABLE 8

Analysis of samples collected June 2, 1921

SAMPLES	COLONIES PER CUBIC CENTIMETER			FERMENTATION TESTS			
				Lactose broth 37°C.			
				24 hours		48 hours	
	Plain agar 20°C.—48 hours	Litmus lactose agar 37°C.—48 hours	Acid colonies	10 cc.	1 cc.	10 cc.	1 cc.
Raw water, N. P. Laundry	420–290	190–120	0–0	0/1	0/2	1/1	0/2
Filtered water, N. P. Laundry.....	1000–600	2100–1800	0–0	0/1	0/2	0/1	0/2
Raw water, Close Hall.....	140–260	260–250	0–0	0/1	0/2	1/1	2/2
Refinite filtered water, Close Hall.....	100–150	200–350	0–0	0/1	0/2	0/1	0/2
Permutit filtered water, Close Hall.....	160–200	250–225	0–0	0/1	0/2	1/1	0/2
Borromite filtered water, Close Hall.....	200–200	300–500	0–0	0/1	0/2	1/1	0/2

Note: Gas production in the 10 cc. tubes of the raw water, Close Hall and that passing the permutit and borromite filters, when confirmed, gave positive tests for B. coli.

TABLE 9

Analysis of samples collected June 6, 1921

SAMPLES	COLONIES PER CUBIC CENTIMETER			FERMENTATION TESTS			
				Lactose broth 37°C.			
				24 hours		48 hours	
	Plain agar 20°C.—48 hours	Litmus lactose agar 27°C.—24 hours	Acid colonies	10 cc.	1 cc.	10 cc.	1 cc.
Raw water, N. P. Laundry..	120–160	100–87	0–0	0/1	0/2	0/1	0/2
Filtered water, N. P. Laundry.....	340–220	600–750	0–0	0/1	0/2	0/1	0/2
Raw water, Close Hall.....	8–10	200–225	0–0	0/1	0/2	0/1	2/2
Refinite filtered water, Close Hall.....	190–180	280–260	0–0	0/1	0/2	0/1	0/2
Permutit filtered water, Close Hall.....	150–160	250–240	0–0	0/1	0/2	0/1	1/2
Borromite filtered water, Close Hall.....	150–190	200–210	0–0	0/1	0/2	0/1	0/2

Note: Confirmation test showed absence of B. coli in the 1 cc. permutit passed sample.

hypochlorite used contained an available chlorine content of 2 per cent. Immediately after the introduction of the salt and the hypochlorite, the washing of the unit was started. In all tests, as shown

TABLE 10

Analysis of samples collected June 7, 1921

SAMPLES	COLONIES PER CUBIC CENTIMETER			FERMENTATION TESTS			
				Lactose broth 37°C.			
				24 hours		48 hours	
	Plain agar 20°C.—48 hours	Litmus lactose agar 37°.C—24 hours	Acid colonies	10 cc.	1 cc.	10 cc.	1 cc.
Raw water, N. P. Laundry..	7–8	6–5	0–0	0/1	0/2	0/1	0/2
Filtered water, N. P. Laundry.....	24–55	100–120	0–0	0/1	0/2	0/1	0/2
Raw water, Close Hall.....	10–15	160–180	0–0	0/1	0/2	0/1	0/2
Refinite filtered water, Close Hall.....	220–250	310–310	0–0	0/1	0/2	0/1	0/2
Permutit filtered water, Close Hall.....	140–150	87–75	0–0	0/1	0/2	0/1	0/2
Borromite filtered water, Close Hall.....	52–48	120–170	0–0	0/1	0/2	0/1	0/2

by the starch iodide test, the excess chlorine was completely washed out before soft water was obtained. Continuous softening experiments were made and samples were collected at intervals for analysis.

The results are given in tables 11, 12, 13, and 14.

TABLE 11

Sterilization with 100 cc. and 200 cc. sodium hypochlorite

SOURCE OF SAMPLE	COLONIES PER CUBIC CENTIMETER OF WATER					
			Softener no. 1 100 cc. sodium hypochlorite		Softener no. 2 200 cc. sodium hypochlorite	
	24 hours	48 hours	24 hours	48 hours	24 hours	48 hours
Raw water	70	300				
End of salting			10	150	0	4
End of 300 gallons			70	170	26	64
End of 800 gallons			70	192	70	140

TABLE 12

Sterilization with 50 cc. sodium hypochlorite

SOURCE OF SAMPLE	COLONIES PER CUBIC CENTIMETER OF WATER					
			Softener no. 1		Softener no. 2	
	24 hours	48 hours	24 hours	48 hours	24 hours	48 hours
Raw water	15	69				
End of salting			5	23	23	54
End 300 gallons			No test		No test	
End 800 gallons			34	71	22	63

TABLE 13

Sterilization with 25 cc. sodium hypochlorite

SOURCE OF SAMPLE	COLONIES PER CUBIC CENTIMETER IN WATER					
			Softener no. 1		Softener no. 2	
	24 hours	48 hours	24 hours	48 hours	24 hours	48 hours
Raw water	16	Spreader				
During salting—still a test for Cl.			2	2	2	2
End of 300 gallons			No test		No test	
End of 800 gallons			96	140	77	130

At the end of these tests an experiment was made on the softeners to determine the minimum amount of sodium hypochlorite that could be used and still obtain a starch iodide test through the softeners. Ten cubic centimeters and 15 cc. gave strong tests, while 5cc. gave only a very faint test.

Softening experiments which were run along with the sterilization experiments showed that the softening power of the borromite was not apparently affected by the hypochlorite treatment.

TABLE 14

Sterilization with 20 cc. sodium hypochlorite

SOURCE OF SAMPLE	COLONIES PER CUBIC CENTIMETER OF WATER					
			Softener no. 1		Softener no. 2	
	24 hours	48 hours	24 hours	48 hours	24 hours	48 hours
Raw water	5	62				
During salting—still a test for Cl....			2	2	2	27
End of salting			44	210	16	150
End of 500 gallons			103	225	91	240
End of 800 gallons			61	310	39	250

III. DISCUSSION OF RESULTS AND THEORETICAL CONSIDERATIONS

It is evident that the common zeolitic water softeners do not produce a sterilizing action. Newly prepared permutit may possess a sterilizing action due to its strongly alkaline reaction, but if it has this property it disappears with use. It is true, when a highly contaminated water is filtered through the zeolites, there is a material reduction in the number of bacteria. They do not, however, possess this property to any greater extent than does sand. It would seem, therefore, that their action must be largely a mechanical one, not due to any *special* adsorptive powers of the zeolites. It is not difficult to understand why refinite and permutit, although much coarser in texture than the sand and borromite should give almost as good bacterial removal. It is a well known fact that a sand filter does not effectively remove bacteria until a schmutzdecke is formed, and the bacterial removal is largely in this covering. During the course of the laboratory experiments, the formation of an effective covering of this sort was impossible. Due to the coarser texture (table 4)

of refinite and permutit, its formation would be greatly retarded while it should form as well on borromite as on sand. It is probable that if the experiments had been extended that far, more efficient bacterial removal would have resulted. In actual operating conditions, however, zeolitic water softeners do not form a very heavy *schmutzdecke*. A clear water must be used, for if it is not, the grains become coated and the softening properties are greatly impaired. Hence, the experiments were not carried to that point. The laboratory experiments show conclusively that B. coli is not quantitatively removed.

As shown by the tests upon the New Process Laundry permutit installation and the domestic softeners previously described, it is evident that the bacterial counts may, and in most cases where a water of low bacterial content is used do, increase upon filtration. This may be due to several causes, one of which is evidently the external pollution brought about during reconditioning. During operation the filters collect considerable slime, particularly if a perfectly clear water is not being used and if the filter is not thoroughly backwashed preceding the reconditioning. This material offers an excellent medium for bacterial multiplication. Where softeners stand idle for some time bad odors often result, due to anaerobic bacterial action and the bacterial count may increase to an extremely large number. The importance of a thorough backwash cannot be too strongly emphasized, as it is essential, not only for minimizing the bacterial multiplication, but also for the best softening conditions. It is possible, though not highly probable, that some bacteria may be absorbed along with the hardening salts and it is difficult to remove them with a vigorous backwash.

Although the bacterial counts on the filtered water may increase over that of the raw water with a small number of organisms, there may be no other indications that the water is not suitable for drinking. The absence of all gas formers, in all cases where they were absent in the raw water, is important.

It is frequently remarked that zeolitic-softened waters have a "flat" taste. This is quite true, but the objection to the flat taste usually disappears as one becomes accustomed to the water. In spite of the entire absence of hardening salts, which have been removed by the zeolites, the water after carbonating is free from the objectionable flat taste. Such softened waters should be suitable

for bottled drinks, if sterilized previous to use, since all the objectionable salts have been removed. In many cases the troubles which render bottled drinks unmerchantable are due to fermentation of the sugars employed in the flavoring syrups. The fermentation may be due to bacteria or to yeasts.

It is claimed that people suffering from gall stones may get relief by drinking zeolitic softened waters, but the author cannot vouch for the truth of the statement.

IV. CONCLUSIONS

Zeolitic water-softening filters materially reduce the bacterial content of highly contaminated waters, but do not quantitatively remove Bacterium coli. If such a water is to be used for drinking purposes the filtration should be followed by chlorine treatment.

Although a water initially of low bacterial count may increase in bacterial content upon passage through zeolitic filters, there is no evidence for deciding that such a water is unsuitable for drinking purposes, if the raw water is safe. As a factor of safety it may be desirable occasionally to sterilize the filters with sodium hypochlorite or bleaching powder. Liquid chlorine might be used in commercial plants.

Bacterial removal by zeolitic filters is a mechanical phenomenon and is not dependent upon any sterilizing action of the minerals.

A high rate of backwash is desirable for the removal of bacteria from the softeners. If the softeners stand idle for some time they should be opened to allow access of air to prevent anaerobic decomposition of the organic material collected in the filter. They should then be thoroughly backwashed before being put into service again.

Zeolitic softened waters should be suitable for bottled drinks if sterile conditions are maintained. If sugar-splitting organisms are absent in the raw water, zeolitic softened water should be satisfactory for bottled drinks even without sterilization. The use of a stone filter might be advisable after a zeolitic softener to help reduce organic growths in the finished goods.

Of the common zeolitic water softeners borromite seems to possess a somewhat greater ability to remove bacteria. Because of its physical structure and density, it offers the possibility of acting both as a filtering and as a softening medium.

REFERENCES

1. Thos. R. Duggan, Commercial application of artificial zeolites. Orig. Com. 8th Intern. Congr. Appl. Chem. (Appendix), **25**, 125–9; Chem. Abstracts, **7**, 2267.
2. Albert Bencke. The present status of the permutit process for the purification and softening of service and drinking waters. Gesund. Ing. 36, 282–4; Chemical Abstracts **7**, 2268.
3. Anon. German Water Softener, Permutit. Weekly Consular Trade Reports 4, 178; Chemical Abstracts, **4**, 1519.
4. Flinn, Weston and Bogert. Waterworks Handbook, pp. 739–41, New York, 1916.